

**GENDER DIFFERENCES IN MATHEMATICS CURRICULUM-BASED
MEASUREMENT IN THIRD THROUGH EIGHTH GRADE STUDENTS**

**A Thesis
by
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**Submitted to the Graduate School
Appalachian State University
in partial fulfillment of the requirements for the degree
MASTER OF ARTS**

**May 2012
Department of Psychology**

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FOREWORD

This thesis is written in accordance with the style of the *Publication Manual of the American Psychological Association (6th Edition)* as required by the Department of Psychology at Appalachian State University.

ACKNOWLEDGMENTS

I want to thank my thesis committee members, Jamie Y. Fearrington, Pamela Kidder-Ashley, and Shawn Bergman for their guidance and instruction throughout the writing of this thesis. I dedicate this thesis to my parents, Thomas Dickerson and Roberta Blue. Thank you both for all of the love, encouragement, and advice you have given me every single day.

Gender Differences in Mathematics Curriculum-Based Measurement in Third through Eighth

Grade Students

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Abstract

A number of studies have identified differences between males and females in academic performance across the areas of reading, writing, and mathematics (Below, Skinner, Fearington, & Sorrell, 2010; Camarata & Woodcock, 2006; Duckworth & Seligman, 2006; Gibb, Fergusson, & Horwood, 2008; Pomerantz, Altermatt, & Saxon, 2002). The current study is preliminary, examining whether or not gender differences exist when Mathematics Curriculum-Based Measurement (M-CBM) probes are used to assess basic math computation skills in a sample of third through eighth grade students. Participants included 1,627 general and special education students (813 males and 814 females) from five schools in a rural southeastern school district in the United States. AIMSweb M-CBM probes were administered to each student three times (at fall, winter, and spring benchmarks) during the 2006-2007 school year. M-CBM probes were scored for Correct Digits. A mixed model linear regression was used to identify significant differences between genders in grades three through eight. The development of advanced math skills requires knowledge of basic math concepts, such as addition, subtraction, multiplication, and division that are included on M-CBM probes. School psychologists and other educators will benefit from understanding gender gaps that exist between students in early mathematical ability.

Gender Differences in Mathematics Curriculum-Based Measurement in Third through Eighth Grade Students

For decades, researchers have been interested in studying gender differences in both academic achievement and cognitive ability across a wide range of age groups and subject areas including reading, writing, and mathematics. Many studies have examined gender differences among students in the areas of reading and writing using a number of different measures including Dynamic Indicators of Basic Early Literacy Skills (DIBELS; Dynamic Measurement Group, 2009), the Comprehensive Test of Phonological Processing (CTOPP; Torgesen, Wagner, & Rashotte, 1999), Gray Oral Reading Tests-Third Edition (GORT-3; Wiederhold & Bryant, 1992), and narrative and persuasive samples of student writing (Below, Skinner, Fearington, & Sorrell, 2010; Berninger, Nielsen, Abbott, Wijsman, & Raskind, 2008; Jones & Myhill, 2007; Logan & Johnston, 2010; Twist & Sainsbury, 2009). Research in the area of mathematics has generally assessed gender differences using standardized measures of achievement, such as the Scholastic Aptitude Test-Mathematics (SAT-M) and the American College Testing-Mathematics (ACT-M), with results indicating that males perform better than females on such comprehensive standardized measures (College Board, 2005; U.S. Department of Education, 2004). However, when classroom assessments and overall GPA are used to evaluate gender differences in math, a number of studies indicate that girls perform as well as or better than boys (Crosnoe, Riegle-Crumb, Field, Frank, & Muller, 2008; Duckworth & Seligman, 2006; Pomerantz, Altermatt, & Saxon, 2002).

No studies to date have examined whether or not gender differences are apparent when Mathematics Curriculum-Based Measurement (M-CBM) is used to evaluate mathematical ability. M-CBM assess basic math computational skills such as addition,

subtraction, multiplication, and division. The development of these basic skills provides a strong foundation for advancement in the area of mathematics. It is important for educators to be cognizant of any gender differences that may exist across M-CBM scores, as these formative measures are often used to evaluate student improvement, or lack thereof, specifically after the implementation of evidence-based interventions. The reliability and validity of M-CBM has been demonstrated in previous studies (Christ, Scullin, Tolbize, & Jiban 2008; Fewster & MacMillan, 2002; Kelley, Hosp, & Howell, 2008). The current study aims to increase knowledge of any possible gender gap that may exist between students in mathematical ability as measured by tri-annually administered M-CBM probes. Educators will benefit from understanding whether or not differences exist in basic math computation skills between boys and girls and, if so, at which grade level these disparities might arise.

Gender Differences in Intellectual Abilities

Most researchers agree that no difference exists between males and females in overall intellectual ability (Camarata & Woodcock, 2006; Gibb, Fergusson, & Horwood, 2008). However, many studies have found differences when more specific intellectual abilities are compared. Intellectual instruments are often used as predictors of a student's ability to perform school-related tasks. It would be helpful, therefore, to identify gender differences in cognitive ability that may exist, since any discrepancies likely will carry over into math, reading, and writing skills observed in the classroom.

In 2006, Camarata and Woodcock examined gender differences on the Woodcock Johnson Tests of Cognitive Ability (WJ-III; Woodcock, McGrew, & Mather, 2001) and selected achievement areas. These researchers used participants from the normative samples, aged preschool through late adulthood, in order to identify performance differences between

males and females that appear at specific developmental stages. Camarata and Woodcock found that although males and females did not exhibit an overall difference in General Intellectual Ability (GIA), there was a profound gender difference in Processing Speed, as females scored significantly higher than males in this area on the WJ-III assessment batteries. This difference in Processing Speed was increasingly evident in the high school student sample, before subsiding in the young adult cohort. Camarata and Woodcock (2006) make it clear that the difference in Processing Speed does not refer to reaction time. Instead, the observed difference indicates that males performed more poorly than females on timed measures that ask for manipulation of simple information and require sustained attention and involvement. These researchers also identified a significant gender difference in Verbal Ability (Gc), with males scoring significantly higher than females. Verbal Ability is a measure of a student's word knowledge and language skills (Camarata & Woodcock, 2006; Sattler, 2008). Camarata and Woodcock did not identify significant gender differences across any of the other broad cognitive abilities that were measured. Males and females scored similarly on the Long-Term Retrieval, Visual-Spatial Abilities, Auditory Processing, Fluid Reasoning, and Short Term Memory indices.

Gender differences in broad cognitive abilities, such as Processing Speed, may also be apparent on M-CBM scores. Flanagan, McGrew, and Ortiz (2000) defined processing speed as the capacity to sustain attention and engagement while performing cognitive tasks quickly and automatically. In their analysis of achievement differences across gender, Camarata and Woodcock (2006) noted that males performed better than females on untimed math measures, while no significant gender differences were observed on the timed Math Fluency assessment component. Therefore, boys outperformed girls on the untimed measure

but not on the timed measure. These results are somewhat unexpected considering the female processing speed advantage identified by Camarata and Woodcock.

Gender Differences in Academic Achievement

Duckworth and Seligman (2006) distinguished between three types of assessment methods: report card grades, achievement tests, and intelligence tests (commonly referred to as IQ tests, as they yield an intelligence quotient). Each of these measures varies in the amount of continued self-control that is necessary for high performance. According to Duckworth and Seligman, in order to have high report card grades students must be able to study for exams, turn in assignments and projects in a timely fashion, and prepare for class discussions. Since high report card grades depend on student performance throughout the school year, more sustained effort, engagement, and self-discipline is needed than on standardized academic or IQ tests, which last only a matter of hours.

Duckworth and Seligman conducted two different studies, each using a sample of eighth grade students from a magnet public school located in the Northeast (both studies were described in the same paper). For Study 1 researchers administered a battery of self-discipline measures to the eighth graders, including a self-report and delay of gratification questionnaire. Parents and teachers of the participants were also asked to fill out rating scales to measure student self-control. School records were gathered to obtain report card grades, school attendance, and standardized achievement test scores. From Study 1, Duckworth and Seligman were able to conclude that girls do earn higher report card grades than boys. This advantage was found to be substantially higher than the female advantage seen on the standardized achievement test scores. The self, parent, teacher, and delayed gratification questionnaires all indicated that girls are more self-disciplined than boys. As

hypothesized, the advantage in self-discipline had a greater relationship to report card grades than to the standardized achievement measure. The smaller difference in performance on the standardized achievement measure suggests that boys do not find it as difficult to maintain attention during a test that takes a matter of hours, but they may struggle more than girls when it comes to sustained effort throughout an academic year.

In the second study described in Duckworth and Seligman (2006), another sample of eighth grade students was administered the same battery of self-discipline questionnaires and the Otis-Lennon School Ability Test- Seventh Edition (Harcourt Brace Educational Measurement, 1997) as a measure of cognitive functioning. Results supported the conclusions from Study 1, where girls were found to be more self-disciplined than boys and earned higher report card grades. However, males significantly outperformed females on the intelligence measure, providing further evidence that self-discipline is not as strongly associated with standardized test performance as it is with report card grades. Results from this study were inconsistent with previous research that has identified no difference between males and females in overall IQ (Camarata & Woodcock, 2006).

As part of a study by Pomerantz et al. (2002), grades were collected in four subject areas: language arts, social studies, science, and math to assess differences between boys and girls in academic performance. Participants included 932 elementary school students in the fourth, fifth, and sixth grades. Children's "internal distress" was also measured using self-evaluation procedures. Their results indicated a small, but notable, gender difference in academic performance, with females showing the advantage. Pomerantz et al. also found that girls reported a greater amount of internal distress as compared to boys and were more likely to report worry about their academic performance.

In 2009, Matthews, Ponitz, and Morrison examined the behavioral self-regulation of kindergarteners and how it relates to their early achievement across five academic areas, as assessed by the WJ-III (Woodcock et al., 2001). The subtests used to assess academic achievement included Applied Problems (Math), General Knowledge, Letter-Word Reading, Vocabulary, and Sound Awareness. Matthews et al. defined self-regulation as the ability to incorporate attention and inhibitory control to produce desired behavioral responses in the classroom (e.g., following specific directions), maintain focused effort towards the performance of cognitive tasks, and exhibit appropriate social behavior by handling aggression towards classroom peers. A number of researchers have found that self-regulation can strengthen academic performance by fostering a student's engagement and motivation (Fredricks, Blumenfeld, & Paris, 2004; Matthews et al., 2009; Zimmerman & Schunk, 2001). Therefore, Matthews et al. (2009) suggest that a gender difference in behavioral self-regulation may lead to differences in achievement outcomes for males and females.

In their study, Matthews et al. gave a direct assessment called the Head-Toes-Knees-Shoulders task (HTKS; Diamond, Kirkham, & Amso, 2002) and asked teachers to complete the Child Behavior Rating Scale (CBRS; Bronson, Goodson, Layzer, & Love, 1990) in the spring to evaluate the behavioral self-regulation of kindergarteners. The HTKS task required children to remember directions and rules given by the researcher (i.e., to maintain attention and apply efficient use of working memory) and to resist certain impulsive reactions. First, the children were instructed to follow a simple command such as "Touch your knees." Then, the same children were asked to perform an action that conflicted with the original command.

For example, the correct response may be to actually touch one's knees when the researcher says "Touch your head" (Matthews et al., 2009).

Results from these two measures showed that females were better able to self-regulate behavior. These researchers did not find that self-regulation predicted achievement across all domains assessed for students as young as kindergarten. They speculated that this may be due to the fact that kindergarten does not present as many academic challenges as do higher grades. However, Matthews et al. did find correlations between self-regulation and the academic areas of math and sound awareness. One possible reason for this result is that the Applied Problems and Sound Awareness tasks required working memory and inhibitory control of incorrect responses, both of which are higher-order cognitive abilities that were also necessary for the self-regulation HTKS task. These researchers further suggest that in order to learn mathematics, even at the kindergarten level, behavioral self-regulation is needed.

Gender Differences in Mathematics Achievement

Most researchers have concluded that, although males once exhibited higher math achievement and greater persistence than females, this gap has narrowed in recent years, in part due to an increased interest among girls for taking higher level math courses such as calculus (Bae, Chow, Geddes, Sable, & Snyder, 2000; Crosnoe et al., 2008; Shettle et al., 2007; Xie & Shauman, 2003). Crosnoe et al. (2008) were interested in studying how varying peer relations among adolescents may influence students to enter a particular math "pathway" in school. More specifically, these researchers investigated how boys' and girls' math-course-taking decisions in one year, as well as their academic achievement, affect their enrollment in math courses in the next academic year. The study identified two different

levels of the peer context in school. The first level includes a student's close circle of friends, while the second level refers to course mates who enroll in many of the same classes and share a similar academic track or interest. Data from this study suggested that, for both boys and girls, as students had access to more course opportunities at the end of high school, they were more consistently affected by the peer context in their math course decisions. Their findings showed that both the close friends' achievement and course mates' achievement influenced female students' math-course-taking decisions in the later grades, while only the close friends' achievement contributed to male choices. Crosnoe et al. concluded that while both levels of the peer context influenced males and females, there was a tendency for females to be influenced more by their close friends than by the broader peer context that includes course mates.

In 2010, Else-Quest, Hyde, and Linn conducted a meta-analysis to examine the underrepresentation of females in careers that involve mathematics, science, technology, and engineering. These researchers analyzed results from two large international data sets to determine the extent to which gender differences exist across 69 nations in mathematics achievement, attitudes, and affect. The two assessments used to compare math achievement and attitude across genders in this meta-analysis were the Trends in International Mathematics and Science Study (TIMSS; Mullis, Martin, Gonzalez, & Chrostowski, 2004) and the Programme for International Student Assessment (PISA; Organisation for Economic Co-operation and Development (OECD), 2004). Individuals who took the TIMSS were in the eighth grade and individuals who took the PISA were between 15 years, 3 months and 16 years, 2 months. The TIMSS is grounded in the curriculum and focuses on skills students have acquired in the classroom. The PISA evaluates mathematics literacy, focuses more on

the application of math facts in the world, and involves a more thorough understanding, or depth of knowledge, of mathematical concepts than the TIMSS.

There has been some focus in past research on the “greater male variability hypothesis,” which suggests that males perform better than females on mathematical tasks that involve higher-order, more complex problem solving. If this assertion is true, then a larger gender difference would be apparent on more challenging assessments of mathematical ability. Since a difference in the complexity of skills measured on the TIMSS versus the PISA has been noted, the greater male variability hypothesis would predict a larger gender difference on the PISA. Each of these assessments also included scales to measure students’ attitudes and affect about mathematics. Scales on the TIMSS include Self-Confidence in Mathematics and Students’ Valuing Mathematics (Mullis et al., 2004). Scales on the PISA include Extrinsic Motivation, Intrinsic Motivation, Anxiety in Mathematics, Self-Concept in Mathematics, and Self-Efficacy in Mathematics (OECD, 2004).

The results of this meta-analysis found that a gender gap in mathematics achievement did exist in some nations, but not in others. However, in most nations, this difference was small ($d < 0.15$), suggesting that, overall, males and females performed similarly in the area of mathematics. The TIMSS did identify more similarity between male and female math performance than the PISA. Although a slight male advantage was noted on the PISA, this difference was very small and did not provide strong support for the greater male variability hypothesis. Despite the fact that very small differences were found between males and females in math achievement, females did exhibit more anxiety and less confidence in their ability to do math. Boys were also found to be more extrinsically and intrinsically motivated to perform well in the area of mathematics than their female counterparts. Else-Quest et al.

(2010) attribute this attitude difference between males and females in part to the gender stratification hypothesis. This hypothesis proposes that when females perceive themselves as being unequal to males (for example, having lower social status), they are more likely to hold negative opinions about math. One predictor of the gender gap in math achievement, attitudes, and affect identified by Else-Quest et al. was the number of research jobs held by males versus females in a particular area. That is, in a nation where women were more likely to have a career involving mathematics, science, technology, or engineering, young girls were less likely to feel anxious about math courses or tests. When girls are encouraged by parents and teachers to excel in math and have obvious female role models succeeding in this area, girls are more likely to develop a positive attitude towards this subject.

Hyde, Lindberg, Linn, Ellis, & Williams (2008) compiled end-of-grade assessment data from ten different states to compare math performance of males and females using a cross-sectional research design. According to Hyde and her colleagues, the 10 states included in this study were representative of the United States as a whole. Results revealed no difference in math skills across gender for students in grades 2 through 11. In a follow-up study conducted by Scafidi and Bui (2010), similar results were found. These researchers used a longitudinal design with students in middle school through high school. Despite negative stereotypes that assume girls will not perform as well as boys in the area of mathematics (Cavanagh, 2008), no difference was found between males and females in performance on a standardized test of math ability.

Theories of Gender Differences

Past researchers have attempted to understand the female advantage seen when report card grades are used to measure educational attainment across all subject areas (Gibb et al.,

2008; Kenney-Benson, Pomerantz, Ryan, & Patrick, 2006). Several hypotheses have been offered to explain why this advantage is seen including the possibility of a discrepancy in cognitive ability; a difference between males and females in their approach to schoolwork; and differences in adopted learning strategies, classroom behavior, self-regulation, math self-efficacy, and the planning and attention strategies of students.

Gibb et al. (2008) conducted a longitudinal study to identify gender differences in educational achievement across a group of 1,265 participants, followed from birth to age 25. Results found that males performed worse on standardized achievement measures in the areas of word recognition, reading comprehension, and mathematical reasoning. It was also determined that males received fewer educational qualifications post high school than females. Educational qualifications included attending a university or earning a bachelor's degree or higher by the age of 25. Gibb et al. considered two popular hypotheses: that either a gender discrepancy in cognitive ability or a noticeable difference in classroom behavior between boys and girls could explain this female advantage in educational outcomes. Individuals at ages 8 and 9 were administered the Wechsler Intelligence Scale for Children-Revised (WISC-R; Wechsler, 1974). Gibb et al. found no significant differences between males and females on Verbal IQ, Performance IQ, or Full Scale IQ. Therefore, these results do not provide support for their first hypothesis that a gender difference in cognitive ability is behind the tendency for females to exceed males in educational attainment. In addition to the cognitive measure, Gibb et al. asked teachers to complete behavior inventories for students aged 6, 8, 10, and 12 years to identify gender differences in classroom behavior, as measured by teacher ratings. The assessment items were adapted from the Connors (1969) and Rutter, Tizard, and Whitmore (1970) questionnaires for teachers. Results revealed that teachers

generally described boys as showing significantly higher levels of “distractible, restless, inattentive behavior and aggressive, antisocial, oppositional behavior” than females (Gibb et al., 2008, p. 65). Therefore, the hypothesis that classroom behavior might account for gender differences in educational performance was supported by this research.

Kenny-Benson et al. (2006) acknowledge that girls tend to make better grades than boys across a number of subject areas. These researchers examined whether or not a difference in how each gender approaches schoolwork might account for the better performance of females. These researchers distinguished between three different kinds of achievement goals that students develop and apply to learning in the classroom: mastery goals, performance goals, and performance-avoidance goals. Students who have developed mastery goals are concerned with actually learning the material or content, while those who value performance goals desire only to make good grades and perform at a higher level than classroom peers. A performance-avoidance goal develops when a student puts forth effort in order to avoid performing worse than other students in the classroom.

Kenny-Benson et al. (2006) conducted two rounds of data collection with 518 students in the 5th grade and again when they reached 7th grade. Participants were administered a number of surveys to assess their approach to school, disruptive behavior, learning strategies (self-regulated versus lack of persistence), and math self-efficacy. Math achievement test scores and math grades were also gathered from students' school records in both the 5th and the 7th grades. Consistent with other research in this area that identifies the female advantage as being most pronounced on report card grades (Duckworth & Seligman, 2006), Kenny-Benson et al. found that girls received higher grades in math than boys. In fact, math grades for girls increased from 5th to 7th grade, while boys' grades showed no

change over time. However, girls did not perform better than boys on math portions of the standardized achievement measures. These researchers concluded that girls tend to develop more positive learning strategies, as they are more likely to choose mastery over performance goals and do not exhibit disruptive behavior in the classroom as often as boys. Boys, on the other hand, are more likely to maintain performance over mastery goals and report more instances of disruptive behavior, which may eventually lead to inefficient learning strategies in school. The tendency for girls to foster more positive learning strategies helps explain why they have higher classroom grades than boys. These positive learning strategies do not, however, appear to affect performance on standardized achievement measures, since results do not identify a female advantage in this area. Rather, these researchers explained that self-efficacy is a better predictor of standardized achievement performance, and that girls often do not feel as confident in taking large-scale assessment measures, particularly in stereotypically masculine areas such as math (Kenny-Benson et al., 2006).

In 2001, Naglieri and Rojahn examined gender differences among 2,200 girls and boys aged 5-17 years using a cognitive-processing theory. These researchers used the Cognitive Assessment System (CAS; Naglieri & Das, 1997), which yields scores of four specific scales including Planning, Attention, Simultaneous, and Successive (PASS), as well as a Full Scale IQ score. Results from this study found that girls outperformed boys on measures of Planning and Attention. Basic math calculation skills require the use of planned strategies, which may explain why girls have been found to perform better on basic arithmetic tests in the elementary and middle school grades (Geary, 1994). These findings indicate that boys may need more assistance and explicit instruction in strategic planning when performing math calculation problems as well as coaching on how to better regulate

attention to specific classroom tasks (Naglieri & Rojahn, 2001). These results could have implications for the current study, since the M-CBM probes consist of basic mathematical computation problems including addition, subtraction, multiplication, and division.

Purpose of the Current Study

The purpose of the current study is to determine whether or not gender differences exist in basic mathematical skills, as assessed by the M-CBM probes. These probes consist of basic math computational problems that require addition, subtraction, multiplication, and division skills. Research has shown that the development of these early math skills impacts the development of higher-order math abilities (U.S. Department of Education, 2008). M-CBM probes are used as part of a universal screening process, as progress monitoring tools, and can be used to aid special education eligibility decision-making. It is, therefore, important to identify whether or not gender differences do exist and, if so, at which grade level they might arise. The current study examined the following three research questions:

1. Will gender differences be found in students' performance on CBM assessments of mathematical skills?
2. If differences are found, is there a specific age or grade of onset when they begin to appear?
3. If differences are found, what is the pattern across grade levels and time of year?

Hypotheses

Previous researchers have identified differences in the performance of girls and boys on report card grades and standardized achievement measures in the area of mathematics. Although previous research has been mixed, boys have the advantage when standardized tests of achievement are used, but girls tend to hold the edge when report card grades are

used to evaluate performance. A number of research studies have identified that girls are far better than boys at self-regulating behavior and are less likely to be disruptive and inattentive at school. Former studies have also revealed a significant female advantage in processing speed. This indicates that males tend to perform worse on timed measures that require manipulation of simple information (Camarata & Woodcock, 2006). M-CBM probes represent timed measures that are tied to the curriculum and are administered in a group format. The group format may lead boys to be more disruptive, less focused, and less self-regulated than girls when completing probes. For these reasons, in the current study we expect to find gender differences in M-CBM scores beginning at third grade. Overall, we expect that a female advantage in M-CBM scores will be present at each grade level assessed, third through eighth.

Method

Participants

The current study included 1,627 students in grades three through eight from both general and special education classes. There was an equal number of male and female participants in this sample (814 females and 813 males), and all students were from five schools in a rural southeastern United States school district. See Table 1 for sample ethnicity characteristics. Students' math skills were measured at three separate benchmarks during the 2006-2007 school year. Researchers were granted approval from the public school system on May 13, 2008 (see Appendix A for letter). This study was carried out in accordance with ethical research standards and was approved by the Appalachian State University Institutional Review Board (IRB) on January 7, 2011 (See Appendix B).

Description of Measure

Each participant completed an AIMSweb M-CBM benchmark probe three times during the 2006-2007 school year (Pearson, 2011). M-CBM probes are often used as part of a universal screening process or for progress monitoring purposes where student improvement towards instructional goals is evaluated. As with other curriculum-based measures, M-CBM probes are sensitive to change, easy and quick to administer and score, and have a large number of alternate forms available (Shinn, 2005). The reliability and validity of this measure has been established in former research studies (Christ et al., 2008; Clarke & Shinn, 2004; Kelley et al., 2008). M-CBM probes are scored for Correct Digits (CD), which means students are able to receive partial credit for partially correct answers. For example, if a student writes an answer of 14, but the correct answer is 13, he or she will receive one point instead of two, since the digit in the tens-place is correct. Depending on grade level, students have either 2 or 4 minutes to work on each M-CBM probe. Students in grade 3 had 2 minutes, while students in grades 4 through 8 each had 4 minutes. In the time allotted, students try to answer as many math computation problems as possible (Shinn, 2005). Probes consist of basic computational math problems including addition, subtraction, multiplication, and division, and the level of difficulty for each measure rises as the grade level increases. A copy of a sample probe and the standardized directions can be found in Appendix C and Appendix D, respectively.

Procedures

AIMSweb M-CBM probes were administered to students during routine benchmark periods in the fall, winter, and spring of the 2006-2007 academic school year. Each student completed as many math computation problems as possible during a designated amount of

time, either 2 or 4 minutes, depending on the grade of the student. School psychologists, classroom teachers, and teaching assistants within the district were responsible for the administration and scoring of the math probes. Each of these individuals was trained in standardized administration and appropriate scoring procedures. Probes were administered in a group setting, took about five minutes to finish for each class, and were scored as soon as administration was completed.

Examiners were instructed to pass out the M-CBM probes before reading the following instructions:

We're going to take a 4-minute [2-minute] math test. I want you to write your answers to several kinds of math problems. Look at each problem carefully before you answer it. When I say begin, write your answer to the first problem (demonstrate by pointing) and work across the page. Then go to the next row. Try to work each problem. If you come to one you really don't know how to do, put an "X" through it and go to the next one. If you finish the first side, turn it over and continue working. Are there any questions? (Pause). Begin. (Start the timer or stopwatch). Stop, put your pencils down (Shinn, 2005; See Appendix C).

Once completed, student probes were scored for the total number of CD.

Analyses

A causal-comparative cross-sectional and longitudinal design will be used for the current study. The same participants were used across the fall, winter, and spring benchmarking period, while at the same time comparing scores across grade level (3-8). A mixed model linear regression was used to identify significant differences between genders in the third through eighth grades, while controlling for grade level and time of year. Gender served as the independent variable while M-CBM scores at the fall, winter, and spring benchmarks represent the dependent variables. Cohen's *d* was used to calculate effect sizes, (Cohen, 1988).

Results

A mixed model linear regression was used in the current study to determine significant differences between boys and girls at each grade level assessed. The participants in this study were sampled from five different school districts and are organized across multiple hierarchical levels. For example, the M-CBM scores collected for each student represent the Level 1 variable. Since student scores are nested within varying grade levels and time periods, independence of the data could not be assumed. Therefore, in order to examine if the specific grade of the student or time of year the test was taken had an impact on a student's M-CBM scores, apart from the effect of gender, we employed a mixed model linear regression, (Field, 2009).

The main effects of gender, grade, and time were examined. Table 2 provides a summary of the overall main effects and interactions for this study. Results demonstrated that the main effect for gender was a significant predictor of students' M-CBM scores, $F(1, 1615.21) = 29.24, p < .001$, with girls ($M = 35.52, SD = 14.63$) scoring significantly better than boys ($M = 32.62, SD = 14.51$) across grades 3 through 8 and across each benchmarking period. The effect size between boys and girls was .20. The main effect of time was also found to be a significant predictor of M-CBM scores, $F(2, 2276.99) = 461.78, p < .001$, with students' scores increasing from fall ($M = 28.15, SD = 12.81$) to winter ($M = 36.53, SD = 15.76$) and then from winter to spring ($M = 37.53, SD = 15.39$). The effect size between fall and winter was .58 and the effect size between winter and spring was .06. Finally, grade level was found to be a significant main effect predictor of M-CBM score, $F(5, 1615.21) = 102.12, p < .001$. Table 3 provides the mean overall M-CBM score, effect size, and standard deviation for each grade level.

The analysis revealed two significant two-way interactions in the model. Although there was not a significant interaction between gender and grade, $F(5, 1615.21) = 1.73, p = .125$, indicating that girls performed better at each grade, there was a significant interaction between gender and time, $F(2, 2276.99) = 3.60, p = .027$. Figure 1 depicts girls' and boys' M-CBM scores at the fall, winter, and spring benchmarking periods. Girls' scores were found to be higher than boys' scores at each of the three benchmarking periods, which followed the same pattern as the main effect for gender. However, while boys' scores increased significantly from fall to winter, they did not increase significantly from winter to spring, as evidenced by the overlapping confidence intervals.

The interaction between grade and time was also significant, $F(10, 2276.99) = 28.97, p < .000$. Figure 2 provides the overall mean M-CBM scores for boys and girls combined at each grade level and benchmarking period. In grades 6, 7, and 8 the mean score, for boys and girls combined, decreased from winter to spring.

Finally, there was not a significant three-way interaction between gender, grade, and time, $F(10, 2276.99) = 1.75, p = .065$. Figures 3 through 8 display the mean M-CBM data for each gender at each of the three time points. The boys' mean score was higher than the girls' mean score once, during the winter benchmark in the 3rd grade.

Discussion

This is a preliminary study examining gender differences on AIMSweb M-CBM probes for students in grades three through eight. Participants from five different schools were assessed at the fall, winter, and spring benchmarking periods during the 2006-2007 school year. Researchers sought to uncover overall significant differences between boys'

and girls' scores, as well as to examine the pattern of any differences across grade level and time of year.

A mixed model linear regression was used to analyze the effects of gender, grade, and time of year on student scores. A main effect of gender revealed a significant difference favoring females. Significant main effects were also found for both grade and time of year (i.e., benchmarking period), indicating that both of these variables are important predictors of students' M-CBM scores.

The significant main effect for time revealed that M-CBM scores increased from each benchmark period to the next. However, the overall scores did not increase as drastically from winter to spring as they did from fall to winter. When looking at girls' and boys' M-CBM scores separately, girls' scores are significantly different from winter to spring. However, boys' scores are not significantly different from winter to spring, therefore affecting the overall trend across time.

Although there was a significant main effect for grade level, it is important to note that some means are higher at lower grade levels. There are several characteristics of M-CBM probes that might account for this pattern. For example, as grade level rises, the skills represented on the probes increase in difficulty. Students in the third grade have 2 minutes to complete M-CBM probes, while students in grades 4 through 8 have 4 minutes. Grade 3 probes include only addition and subtraction equations. By Grade 4, multiplication using 0 and 1 as well as simple division problems are added to the probes. The fifth and sixth grade probes include more advanced addition, subtraction, multiplication, and division problems. Finally, the seventh and eighth grade probes require students to solve a number of different equations including converting fractions and decimals, adding fractions, solving "percent of"

problems, long division, multiplication with decimals, etc. When comparing the mean results of this study to AIMSweb national norms from the same school year (Pearson, 2011), it is evident that CD do not always increase from one grade to the next or even from one benchmark period to the next, especially in Grades 6, 7, and 8. These norms are comparable to how students in the current sample, both male and female, performed on the M-CBM probes. A possible explanation for this occurrence is that, as the problems get harder, students will need more time to solve and, therefore, do not get as many CD at certain grade levels or times of year.

Previous studies have examined gender differences in mathematics using summative, standardized assessments administered at one point in the school year (Gibb et al., 2008; Hyde et al., 2008). Others have assessed math skills by observing the ongoing report card grades of students, which are not standardized (Duckworth & Seligman, 2006; Kenney-Benson et al., 2006; Pomerantz et al., 2002). The current study differs from former research in that we have used a standardized, formative measure to assess student performance at three different points during a school year.

Our first research question explored whether or not gender differences would be found in students' performance on CBM assessments of mathematical skills. Results support the hypothesis that gender differences do arise in student M-CBM scores, and a female advantage prevails. There have been no other studies to date that have used M-CBM probes to evaluate gender differences in student scores. Previous researchers have, however, identified a female advantage when report cards were used as an assessment tool (Duckworth & Seligman, 2006; Kenny-Benson et al., 2006; Pomerantz et al., 2002). Another group of researchers, Else-Quest et al. (2010), analyzed data from two standardized assessments of

mathematics achievement, the TIMSS and the PISA. Results indicated that in some nations a small gender difference favoring boys was found. Since this difference was so small, however, Else-Quest et al. concluded that the math achievement scores for boys and girls were similar, overall, across most nations. Comparably, Hyde et al. (2008) found no difference between boys and girls in math achievement after analyzing end-of-grade assessment data across ten different states for students in Grades 2 through 11.

Other studies have found that boys do tend to perform better than girls on standardized assessments of math skills (College Board, 2005; U.S. Department of Education, 2004). This may lead one to assume that boys would do better on the M-CBM, which is also a standardized measure of performance. However, the M-CBM probes, which represent a type of formative assessment, differ from the summative standardized assessments that former researchers have used when evaluating gender differences. First, M-CBM probes are administered at multiple points during the school year and in familiar classroom settings. Many end-of-grade standardized assessments are presented to students in a multiple-choice format, but the M-CBM probes require students to write in their own answers, eliminating the possibility of getting a correct answer from guesswork. The M-CBM is quite brief and only measures basic math fact skills, whereas an end-of grade exam and other standardized summative measures of achievement are typically lengthier and evaluate more complex math reasoning abilities.

The differences in the nature of each type of assessment may explain why our results contradict results of previous studies that examined standardized test score differences in math. Studies have shown that girls tend to have poorer self-efficacy in math than boys (Kenney-Benson et al., 2006). These researchers concluded that self-efficacy is a more

reliable variable than a positive learning approach when predicting student scores on a standardized achievement measure. Kenney-Benson et al. (2006) also found that girls are often less confident than boys when taking high-stakes, large-scale assessments, especially when the test is measuring a stereotypically masculine area such as math. Another group of researchers, Pomerantz et al. (2002), identified a gender difference in the amount of internal distress experienced by students. Girls reported higher levels of distress and were found to worry more often than boys about academic performance. These studies could help explain why girls tend to score lower than boys on longer, more difficult assessments of math skills. The questions on the M-CBMs are similar to what students see in the classroom, so girls may not be as intimidated by these problems. Also, M-CBM assessments are not considered "high stakes" assessments, which may lessen anxiety students harbor about test-taking. Many studies have examined gender differences in math achievement. Results appear to differ slightly depending on the specific type of assessment used to measure performance.

The second research question investigated the specific grade of onset when gender differences on M-CBM probes may arise. A female advantage was found in all grades assessed, beginning in the third grade. These findings support our hypothesis that girls' scores would be higher at each grade level. Several theories have been proposed as to why gender differences might exist in the area of mathematics, or in academic achievement as a whole. For example, earlier research studies have used teacher rating scales to measure the self-regulatory, disruptive, and inattentive behavior of students (Gibb et al., 2008; Matthews et al., 2009). Girls were more often identified as being better able to self-regulate behavior in the classroom and as being less disruptive and inattentive in class than boys. In the present study, the M-CBMs were administered in a group, classroom-like setting. One possible

explanation of the female advantage across all grade levels is that girls are generally more capable than boys of maintaining appropriate behavior in classroom settings, but additional research is needed in this area.

Our third research question for the current study examined the patterns of gender differences across grade levels and time of year. Although the three-way interaction was not significant at the .05 level, a p -value of .065 may be considered marginally significant. Visual analysis of the means at each time period indicates that boys outscored girls only once, during the winter benchmark of the third grade year. At every other grade level, during each benchmarking period, girls scored higher than boys on the M-CBM probes.

Results of the current study also support the findings of Camarata and Woodcock (2006). These researchers did not identify an overall difference in cognitive ability between boys and girls. However, they did find that girls held a significant advantage over boys in the area of processing speed, a narrow reasoning ability that contributes to an individual's overall intelligence score. Since the M-CBM probes are timed, students are asked to quickly calculate basic math computation problems. If girls do hold an advantage over boys in processing speed, this could help explain why they scored consistently higher on the M-CBM probes.

Limitations and Directions for Future Research

To our knowledge, this has been the first study to evaluate gender differences in performance using M-CBM probes. Several limitations of this study are worth consideration. The sample population used in the current study was made up of students in Grades 3 through 8. Future studies should determine whether or not significant differences exist in math computation skills below third and above eighth grade. By expanding the population of

interest, we can begin to understand differences across gender within a broader developmental framework.

In the current study, mathematical ability was evaluated using only one measure: the M-CBM probe. M-CBM probes are limited in that they only measure computational skills. There are, of course, other important components to mathematical ability that may be assessed by other CBM. Future studies could examine gender differences on CBM probes that measure other areas of mathematical ability.

Another possible limitation of the current study is the fact that we used a cross-sectional design to compare students' scores across each grade. A longitudinal design would yield data on the same group of students across time. This might be an important direction for future research, as it would provide information on how mathematical ability changes through the course of development, and the pattern of gender differences across a specific group of students could be assessed.

A final limitation of the current study concerns the characteristics of the sample population. Students came from five schools in a rural southeastern school district in the United States and were largely Caucasian. In order for results to generalize across settings, future research should aim to study a more diverse sample of students who better represent the population at large.

Implications for Practice

It is important for educators to understand where gender differences arise in all areas of academic achievement. This can help teachers establish appropriate instructional strategies for each student. Many school systems across the United States are adopting a response-to-intervention model for determining special education eligibility. Therefore,

CBMs are often used to universally screen for students who are at risk of failure in a certain academic area. The current study has found a female advantage on M-CBM probes, which could mean that boys are more likely to be identified as at risk in this academic area. Consequently, educators will need to focus on how they can tailor instruction to meet boys' specific learning needs.

For example, teachers may want to consider the time of day when math instruction is delivered to students. Previous studies have documented that boys have more trouble than girls regulating their own behavior, as well as maintaining focus and attention towards academic tasks (Duckworth & Seligman, 2006; Matthews et al., 2009). Perhaps morning math instruction would be more effective for boys, rather than late in the school day when students are more tired and ready to go home.

In their book, Horne and Feifer (2007) discussed the importance of making mathematics instruction fun by utilizing creative classroom strategies, as opposed to repetitive speed "skill-drills." Students may become more motivated to perform well in the area of mathematics when teachers help to ignite passion and interest for the subject. For example, hands-on math games and activities, enhancement of problem-solving skills through real-world examples, and guided teacher instruction followed by praise are several ways to help energize students during math classes (Horne & Feifer, 2007). Past research has found that boys tend to worry less about their academic performance than girls (Pomerantz et al., 2002). Therefore, good report card grades may be enough to motivate many girls, while boys may need more active, hands-on experiences to maintain interest and increase daily classroom performance, both behaviorally and academically.

In the current study, an overall female advantage was identified when using M-CBMs to measure performance. Females performed better overall at each grade level and benchmarking period. When examining the overall trend across time, current results show that females' performance increased significantly from one time period to the next. However, males' M-CBM scores did not increase significantly overall from the winter to spring benchmarks.

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Table 1

Sample Characteristics

Ethnicity	Percentage of Participants
Caucasian	94.4
Hispanic	3.40
African American	1.40
Asian American	0.50
American Indian	0.30

Table 2

Summary of Overall Main Effects and Interactions

Source	<i>F</i> (<i>df</i>)	Significance (<i>p</i> -value)
Main Effect of Gender	29.24 (1, 1615.21)	.000
Main Effect of Grade	102.12 (5, 1615.21)	.000
Main Effect of Time	461.78 (2, 2276.99)	.000
Interaction of Gender and Grade	1.728 (5, 1615.21)	.125
Interaction of Gender and Time	3.60 (2, 2276.99)	.027
Interaction of Grade and Time	28.97 (10, 2276.99)	.000
Interaction of Gender, Grade, and Time	1.75 (10, 2276.99)	.065

Table 3

Overall Mean Mathematics Curriculum-Based Measurement Scores (Correct Digits) in Grades 3-8

Grade	<i>M</i> (<i>SD</i>)	Cohen's <i>d</i>	95% CI	
			LB	UB
3	22.14 (7.95)		20.69	23.60
4	38.79 (14.18)	1.45	37.41	40.17
5	35.71 (14.22)	.220	34.51	36.92
6	29.39 (11.90)	.480	28.12	30.67
7	37.58 (13.83)	.630	36.37	38.78
8	40.79 (14.34)	.230	39.59	42.00

Note. CI= confidence interval; LB= lower bound; UB= upper bound

Note. The effect size, Cohen's *d*, represents the difference between that grade level mean and the grade below. Thus, there is no effect size listed in the grade 3 column.

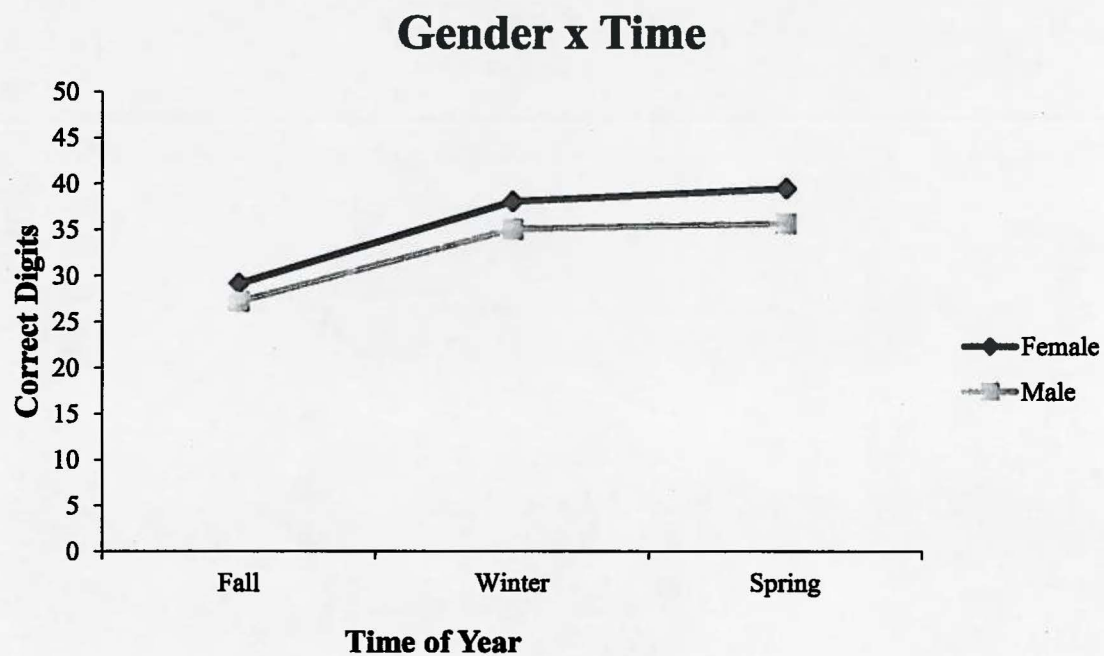


Figure 1. Gender and time interaction. Mean Mathematics Curriculum-Based Measurement scores for males and females at each benchmarking period.

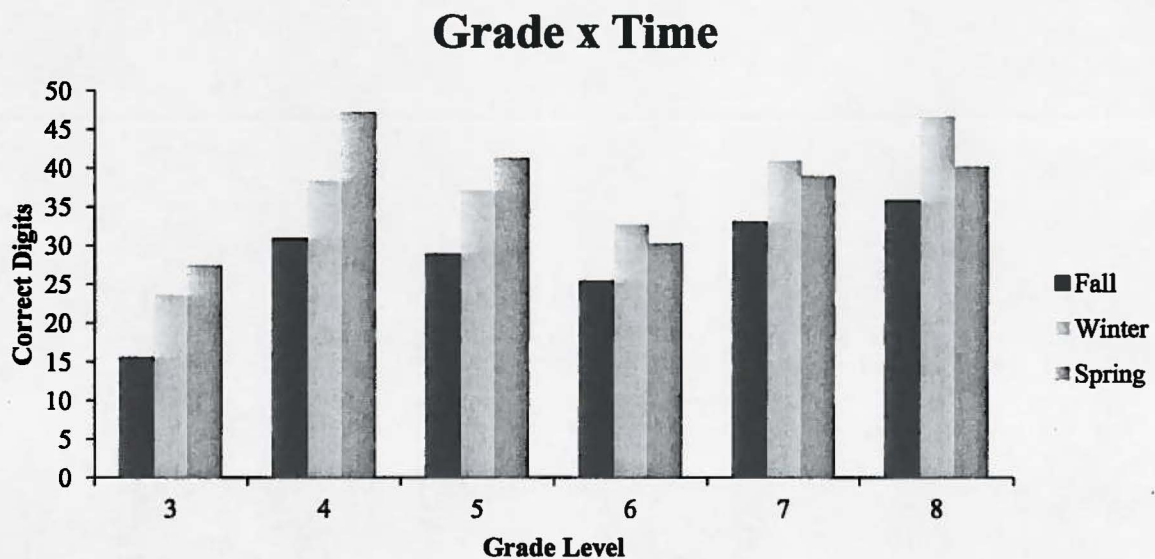


Figure 2. Grade and time interaction. Mean Mathematics Curriculum-Based Measurement scores are represented for each grade level and at each benchmarking period.

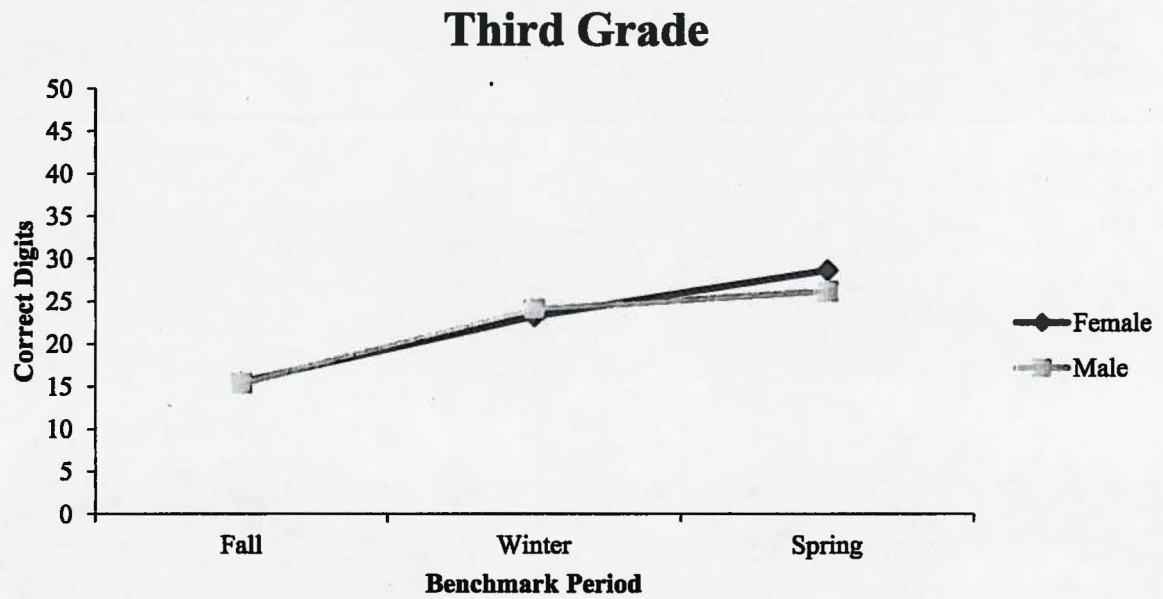


Figure 3. Mean Mathematics Curriculum-Based Measurement scores for 3rd grade males and females at each benchmarking period.

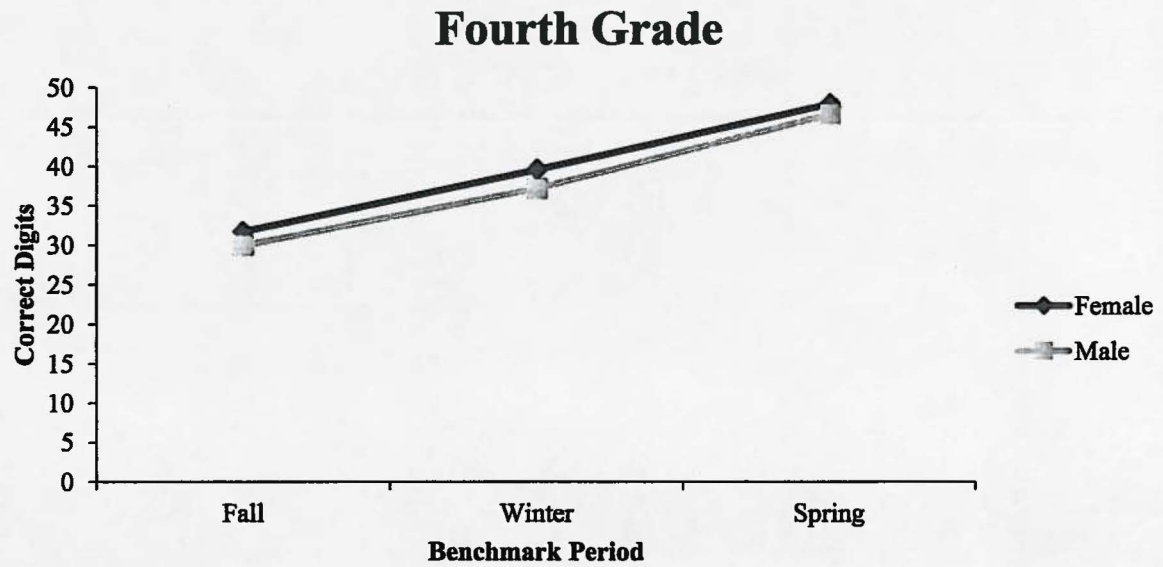


Figure 4. Mean Mathematics Curriculum-Based Measurement scores for 4th grade males and females at each benchmarking period.

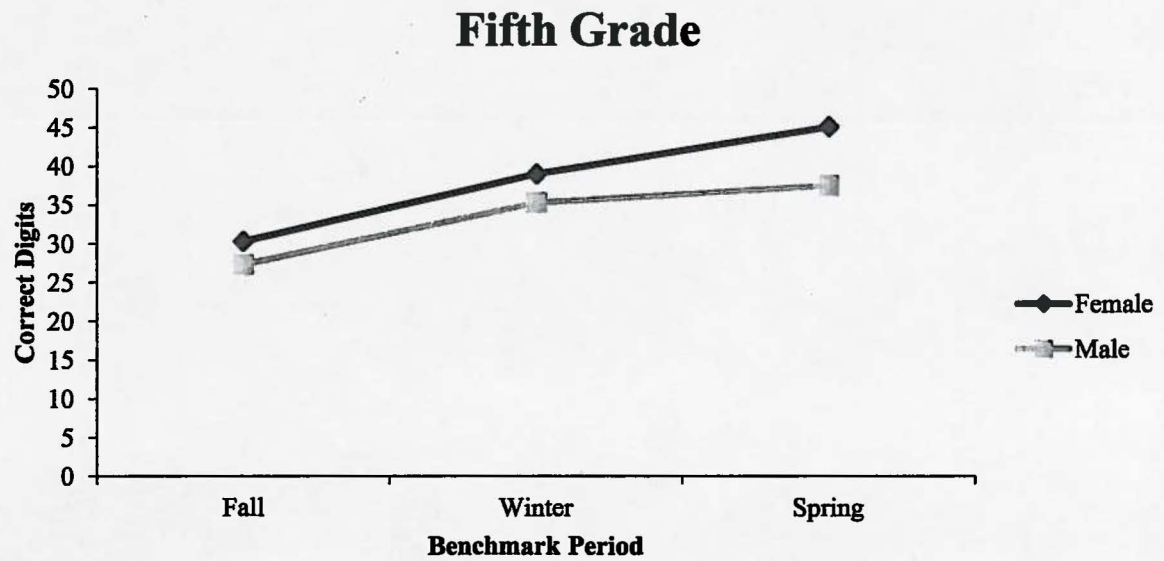


Figure 5. Mean Mathematics Curriculum-Based Measurement scores for 5th grade males and females at each benchmarking period.

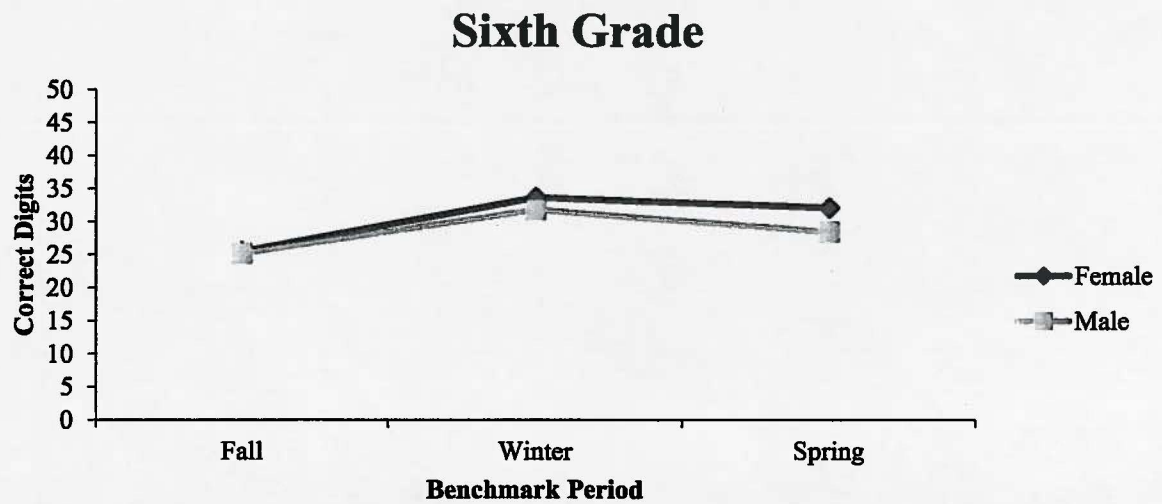


Figure 6. Mean Mathematics Curriculum-Based Measurement scores for 6th grade males and females at each benchmarking period.

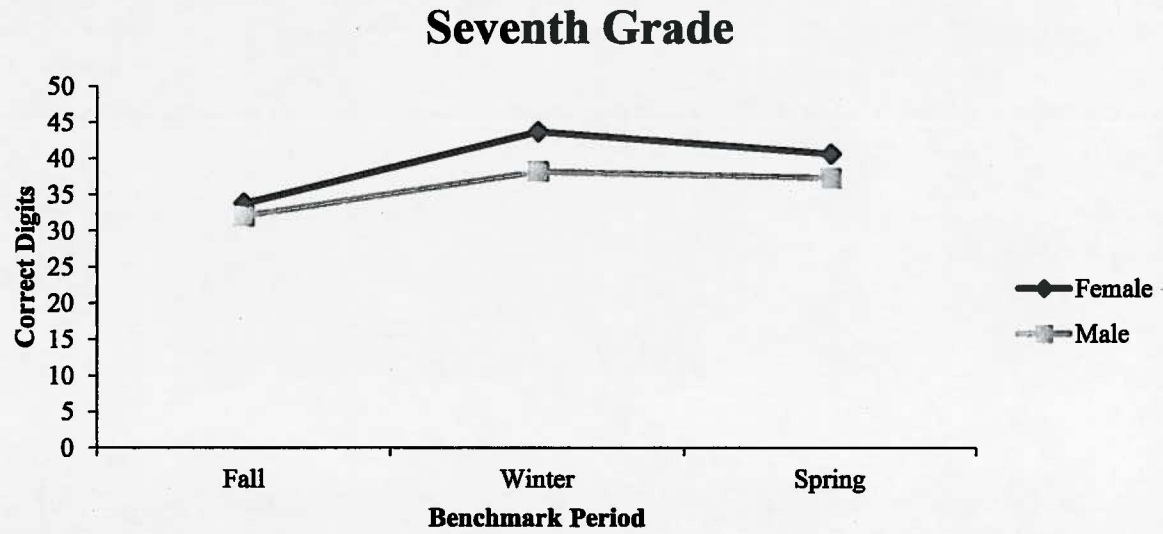


Figure 7. Mean Mathematics Curriculum-Based Measurement scores for 7th grade males and females at each benchmarking period.

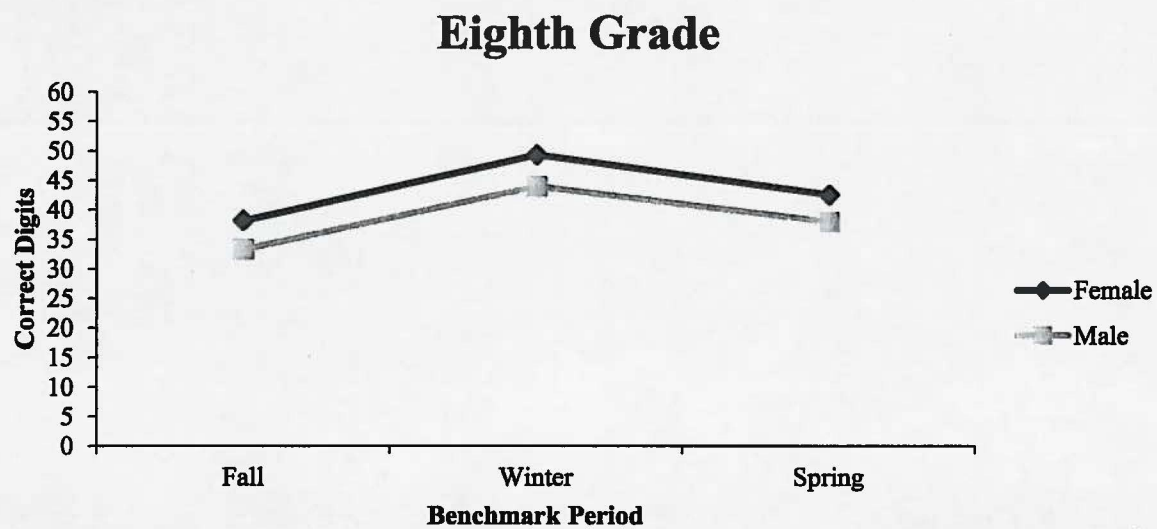


Figure 8. Mean Mathematics Curriculum-Based Measurement scores for 8th grade males and females at each benchmarking period.

Appendix A

Board of Education

JEAN B. ALLISON
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DORIS DAVIS
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2nd District

5-13-2008

To Whom It May Concern:

The purpose of this letter is to grant researchers from Appalachian State University permission to disseminate data that were collected in our system during the 2003-2004, 2005-2006, 2006-2007, 2007-2008, and 2008-2009 school years. It is our understanding that these data were gathered as routine academic screenings and may include benchmark scores, progress monitoring scores, and other standardized test scores. Furthermore, we understand that no specific names of students, teachers, or schools will be communicated. Any other potential identifiers will be removed before these data are disseminated. We grant full permission to the researchers to disseminate these data via publication and presentation. Please do not hesitate to contact me if you have further questions.

Sincerely,



Mike Lowry

Director of Schools

Monroe County School System

Appendix B



INSTITUTIONAL REVIEW BOARD
Office of Research Protections
ASU Box 32068
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Web site: <http://www.orsp.appstate.edu/protections/irb>
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To: Laura Dickerson
Psychology,
CAMPUS MAIL

From: Robin Tyndall, IRB Associate Administrator

Date: 1/07/2011

RE: Determination that Research or Research-Like Activity does not require IRB Approval

Study #: 11-0166

Study Title: Differences in Mathematics Curriculum-Based Measurement in Third through Eighth Grade Students

This submission was reviewed by the IRB. It was determined that it does not constitute human subjects research as defined under federal regulations [45 CFR 46.102 (d or f)] and does not require IRB approval. If your study protocol changes, this determination may no longer apply, and you should contact the IRB before making the changes.

CC:
Jamie Fearington, Psychology

Appendix C

Math Curriculum-Based Measurement (M-CBM)
Standard Directions

Grades 4-6 Probes

1. Students have an M-CBM probe and pencil.
2. Say to the student(s):

"We're going to take a 4-minute math test. I want you to write your answers to several kinds of math problems. Look at each problem carefully before you answer it."

"When I say 'BEGIN,' write your answer to the FIRST problem (demonstrate by pointing) and work ACROSS the page. Then go to the next row."

"Try to work EACH problem. If you come to one YOU REALLY DON'T KNOW HOW TO DO, put an 'X' through it and go to the next one."

"If you finish the first side, turn it over and continue working. Are there any questions? (Pause)"
3. Say "BEGIN" and start your stopwatch/timer.
4. If testing in groups, walk around and monitor students to ensure they are not skipping problems, are working across the page, and continue to write answers to the problems during the test time.

If a student is excessively skipping problems they should know how to do, say to the student:
"Try to work EACH problem. You can do this kind of problem so don't skip or put an 'X' over it."

If a student is not working across the page, say to the student:
"Work ACROSS the page. Try to work each problem in the row."

If a student stops working before the test is done, say to the student:
"Keep doing the best work you can."
5. At the end of 4 minutes, say "Stop. Put your pencils down." Monitor to ensure students stop working.

Appendix D

AIMSweb® M-CBM Computation Progress Monitor #2 - Grade 3

Student Name: _____ Grade: _____ Teacher Name: _____

$\begin{array}{r} 3 \\ + 6 \\ \hline \end{array}$	$\begin{array}{r} 1 \\ + 8 \\ \hline \end{array}$	$\begin{array}{r} 1 \\ + 8 \\ \hline \end{array}$	$\begin{array}{r} 8 \\ + 6 \\ \hline \end{array}$	$\begin{array}{r} 4 \\ - 4 \\ \hline \end{array}$	$\begin{array}{r} 6 \\ - 6 \\ \hline \end{array}$
$\begin{array}{r} 225 \\ + 75 \\ \hline \end{array}$	$\begin{array}{r} 44 \\ + 82 \\ \hline \end{array}$	$\begin{array}{r} 3 \\ - 1 \\ \hline \end{array}$	$\begin{array}{r} 949 \\ + 5 \\ \hline \end{array}$	$\begin{array}{r} 255 \\ + 175 \\ \hline \end{array}$	$\begin{array}{r} 205 \\ 183 \\ + 729 \\ \hline \end{array}$
$\begin{array}{r} 817 \\ 89 \\ + 588 \\ \hline \end{array}$	$\begin{array}{r} 93 \\ - 79 \\ \hline \end{array}$	$\begin{array}{r} 999 \\ + 631 \\ \hline \end{array}$	$\begin{array}{r} 3 \\ + 15 \\ \hline \end{array}$	$\begin{array}{r} 393 \\ - 79 \\ \hline \end{array}$	$\begin{array}{r} 756 \\ - 277 \\ \hline \end{array}$
$\begin{array}{r} 340 \\ + 26 \\ \hline \end{array}$	$\begin{array}{r} 790 \\ + 11 \\ \hline \end{array}$	$\begin{array}{r} 807 \\ - 643 \\ \hline \end{array}$	$\begin{array}{r} 330 \\ + 82 \\ \hline \end{array}$	$\begin{array}{r} 748 \\ 635 \\ + 87 \\ \hline \end{array}$	$\begin{array}{r} 436 \\ 358 \\ + 388 \\ \hline \end{array}$
$\begin{array}{r} 5 \\ 6 \\ + 6 \\ \hline \end{array}$	$\begin{array}{r} 783 \\ - 448 \\ \hline \end{array}$	$\begin{array}{r} 411 \\ + 95 \\ \hline \end{array}$	$\begin{array}{r} 93 \\ - 32 \\ \hline \end{array}$	$\begin{array}{r} 20 \\ + 4 \\ \hline \end{array}$	$\begin{array}{r} 160 \\ - 88 \\ \hline \end{array}$
$\begin{array}{r} 214 \\ + 98 \\ \hline \end{array}$	$\begin{array}{r} 7 \\ - 2 \\ \hline \end{array}$	$\begin{array}{r} 645 \\ - 418 \\ \hline \end{array}$	$\begin{array}{r} 301 \\ - 64 \\ \hline \end{array}$	$\begin{array}{r} 10 \\ - 8 \\ \hline \end{array}$	$\begin{array}{r} 800 \\ - 70 \\ \hline \end{array}$

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VITA

Laura Katherine Dickerson was born in Chapel Hill, NC. She graduated from East Chapel Hill High School in June of 2003. Laura soon moved to the mountains of North Carolina to attend college at the University of North Carolina at Asheville (UNC-A) where she studied Psychology and French. During the fall of 2006, Laura participated in the International Student Exchange Program and traveled to Nantes, France to study French language and civilization for a semester. In December of 2007 Laura received her Bachelor of Arts degree from UNC-A. In August of 2009 Laura moved to Boone, NC to begin her graduate studies in the School Psychology program at Appalachian State University. After completing two years of graduate coursework, Laura worked as a school psychologist intern in Washington County, VA. She graduated in May 2012 with a Master's and Specialist Degree in School Psychology and returned to North Carolina for work.